Department of Transportation
Federal Aviation Administration
Aircraft Certification Service
Washington, D.C.

TSO-C199

Effective
Date: ***{mm/dd/yy}***

Technical Standard Order

Subject: ***Low Power Surveillance Equipment***

1. PURPOSE This technical standard order (TSO) is for manufacturers applying for a TSO authorization (TSOA) or letter of design approval (LODA). In it, we the Federal Aviation Administration, (FAA) tell you what minimum performance requirements your Low Power Surveillance Equipment (LPSE) must first meet for approval and identification with the applicable TSO marking. The intent of an LPSE device is to increase safety within the National Air Space (NAS) by encouraging the voluntary equipage of a low cost, compact, easy to install device that will allow other aircraft equipped with collision avoidance systems and traffic advisory systems to track and display the LPSE aircraft. LPSE devices are intended to be used on aircraft that are exempted from carrying a transponder or Automatic Dependent Surveillance - Broadcast (ADS-B) equipment, such as gliders, balloons and aircraft without electrical systems. LPSE devices do not meet the transponder requirements defined in 14 CFR § 91.215 (b), and 14 CFR § 91.225 (b). LPSE will allow these exempted aircraft to be visible to other aircraft equipped with:

- Traffic Advisory System (TAS) as defined in TSO-C147
- Traffic Alert and Collision Avoidance System I (TCAS I) as defined in TSO-C118
- Traffic Alert and Collision Avoidance System II, (TCAS II), as defined in TSO-C119c
- Aircraft equipped with TCAS II hybrid surveillance as defined in TSO-C119c and
- Aircraft with ADS-B In capability as defined in TSO-C154c, TSO-C166b, and TSO-C195a

2. APPLICABILITY This TSO affects new applications submitted after its effective date.

3. REQUIREMENTS LPSE requirements are derived from existing transponder and ADS-B requirements. Generally, the requirements herein are reduced from the full capability required in the reference documents. The requirements outlined here will allow the

equipment user the capability to be seen by other aircraft equipped with traffic advisory systems but may not support Secondary Surveillance Radar surveillance (SSR) systems. A designer building equipment to meet this TSO may decide to incorporate more capability than what is outlined in this TSO as long as it meets the Minimum Operational Standards (MOPS) outlined in the referenced documents. New models of the LPSE identified and manufactured on or after the effective date of this TSO must meet the MPS qualification and documentation requirements for the applicable equipment class defined by this TSO.

a. Functionality

(1) LPSE developed under this TSO are intended, at a minimum, to make aircraft with an installed device visible to TAS, TCAS I, TCAS II and ADS-B In equipped aircraft. To save energy, LPSE will not be required to reply to ground sensors although in some cases this may be unavoidable (i.e. Mode C). LPSE functionality is divided into four broad categories, the: transponder function, altitude source function, ADS-B Out function, and position source function. LPSE requirements are detailed in **Appendix 1**. LPSE may include an ADS-B In function but it is not required. If implemented, the ADS-B In function should meet the performance specified in, TSO-C154c, TSO-C166b, and TSO-C195a as applicable.

(2) The transponder functionality is essentially a subset of requirements derived from RTCA document DO-181E, *Minimum Operational Performance Standards for Air Traffic Control Radar Beacon System/Mode Select (ATCRBS/Mode S) Airborne Equipment*, dated March 17, 2011, section 2, for a Level 2, Class 2, transponder as modified by **Appendix 1**. LPSE equipment will:

- not reply to Mode S All-Call interrogation (UF=11)
- not reply to ATCRBS / Mode S All Calls
- not reply to Mode A interrogations
- have a reduced reply rate requirement for ATCRBS and Mode S replies and
- have reduced control and display functionality.

(3) The altitude source functionality must meet the requirements of TSO-C88b, *Automatic Pressure Altitude Reporting Code-Generating Equipment*, dated February 6, 2007

(4) The ADS-B Out function is a subset of requirements found in RTCA, Inc. document RTCA DO-260B, *Minimum Operational Performance Standards for 1090 MHz Automatic Dependent Surveillance – Broadcast (ADS-B) and Traffic Information Services – Broadcast (TIS-B)*, dated Dec 2, 2009, section 2, Class B0 as modified by **Appendix 1**.

(5) The position source function must use a GNSS receiver that meets the requirements defined in **Appendix 1**. While an aviation grade GNSS position source that meets a published TSO is desired, it is not required. The system must be built such that it transmits NIC, NACp, NACv, and SIL values appropriate for the GNSS engine used. The system must be capable of detecting signal in space errors and prevent the LPSE transmitting false or misleading information. To support this, the GNSS position source must be screened using the test procedures in **Appendix 2**. The position source must reject the injected errors and either drop the affected pseudorange measurement from the solution, Fault Detection and Exclusion (FDE), or fail the solution. There is no requirement for commercial sensors to work through single

satellite failures. They must detect them and fail the solution at a minimum to be acceptable for use with LPSE.

b. Failure Condition Classifications Failure of the function defined in paragraph **3.a** of this TSO is a minor failure condition for malfunctions causing hazardously misleading information. Loss of the function defined in paragraph **3.a** of this TSO is a minor failure condition. Design the system to at least these failure condition classifications.

c. Functional Qualification Demonstrate the required performance under the test conditions specified in **Appendix 2** of this TSO.

d. Environmental Qualification Demonstrate the required performance under the test conditions specified in RTCA/DO-181E section 2.3, RTCA DO-260B section 2.3, appropriate for the equipment class of the LPSE, using standard environmental conditions and test procedures appropriate for airborne equipment.

> **Note:** The use of RTCA/DO-160D (with Changes 1 and 2 only, incorporated) or earlier versions is generally not considered appropriate and will require substantiation via the deviation process as discussed in paragraph **3.g** of this TSO.

e. Software Qualification If the article includes software, develop the software according to RTCA, Inc. document RTCA/DO-178B, *Software Considerations in Airborne Systems and Equipment Certification*, dated December 1, 1992 to the design assurance level consistent with the failure condition classification defined in paragraph **3.b** of this TSO.

> **Note**: The certification liaison process objectives will be considered satisfied after FAA review of the applicable life cycle data.

f. Electronic Hardware Qualification If the article includes complex custom airborne electronic hardware, develop the component according to RTCA, Inc. Document RTCA/DO-254, *Design Assurance Guidance for Airborne Electronic Hardware* to the design assurance level consistent with the failure condition classification defined in paragraph **3.b** of this TSO.

> **Note**: The certification liaison process objectives will be considered satisfied after FAA review of the applicable life cycle data.

g. Deviations We have provisions for using alternate or equivalent means of compliance to the criteria in the MPS of this TSO. If you invoke these provisions, you must show that your equipment maintains an equivalent level of safety. Apply for a deviation under the provision of 14 CFR § 21.618.

4. MARKING

a. Mark at least one major component permanently and legibly with all the information in 14 CFR § 45.15(b). The marking must include the serial number and functional equipment class in accordance with paragraph 3.

b. Also, mark the following permanently and legibly, with at least the manufacturer's name, subassembly part number, and the TSO number:

(1) Each component that is easily removable (without hand tools); and,

(2) Each subassembly of the article that you determined may be interchangeable.

c. If the article includes software and/or airborne electronic hardware, then the article part numbering scheme must Identify the software and airborne electronic hardware configuration. The part numbering scheme can use separate, unique part numbers for software, hardware, and airborne electronic hardware.

d. You may use electronic part marking to Identify software or airborne electronic hardware components by embedding the Identification within the hardware component itself (using software) rather than marking it on the equipment nameplate. If electronic marking is used, it must be readily accessible without the use of special tools or equipment.

5. APPLICATION DATA REQUIREMENTS You must give the FAA aircraft certification office (ACO) manager responsible for your facility a statement of conformance, as specified in 14 CFR § 21.603(a)(1) and one copy each of the following technical data to support your design and production approval. LODA applicants must submit the same data (excluding paragraph **5.g**) through their civil aviation authority.

a. A Manual(s) containing the following:

(1) Operating instructions and equipment limitations sufficient to describe the equipment's operational capability.

(2) Describe in detail any deviations.

(3) Installation procedures and limitations sufficient to ensure that the LPSE, when installed according to the installation or operational procedures, still meets this TSO's requirements. Limitations must identify any unique aspects of the installation.

(a) The limitations must include a note with the following statement: "This article meets the minimum performance and quality control standards required by a technical standard order (TSO). Installation of this article requires separate approval."

(b) The LPSE manual and installation manual must clearly state "This device does not meet requirements for use in transponder rule airspace as defined in 14 CFR §91.215 and ADS-B rule airspace as defined in 14 CFR § 91.225.

(4) For each unique configuration of software and airborne electronic hardware, reference the following:

(a) Software part number including revision and design assurance level;

(b) Airborne electronic hardware part number including revision and design assurance level;

(c) Functional description; and,

(d) Failure condition classification.

(5) A summary of the test conditions used for environmental qualifications for each component of the article. For example, a form as described in RTCA/DO-160G, *Environmental Conditions and Test Procedures for Airborne Equipment, Appendix 1*.

(6) Schematic drawings, wiring diagrams, and any other documentation necessary for installation of LPSE.

(7) List of replaceable components, by part number, that makes up the LPSE. Include vendor part number cross-references, when applicable.

b. Instructions covering periodic maintenance, calibration, and repair, for the continued airworthiness of LPSE. Include recommended inspection intervals and service life, as appropriate.

c. If the article includes software: a plan for software aspects of certification (PSAC), software configuration index, and software accomplishment summary.

d. If the article includes complex custom airborne electronic hardware: a plan for hardware aspects of certification (PHAC), hardware verification plan, top-level drawing, and hardware accomplishment summary (or similar document, as applicable).

e. Nameplate drawing with the information required by paragraph **4** of this TSO.

f. Identify functionality or performance contained in the article not evaluated under paragraph **3** of this TSO (that is, non-TSO functions). Non-TSO functions are accepted in parallel with the TSO authorization. For those non-TSO functions to be accepted, you must declare these functions and include the following information with your TSO application:

(1) Description of the non-TSO function(s), such as performance specifications and software, hardware, and environmental qualification levels. Include a statement confirming that the non-TSO function(s) don't interfere with the article's compliance with the requirements of paragraph **3**.

(2) Installation procedures and limitations sufficient to ensure that the non-TSO function(s) meets the declared functions and performance specification(s) described in paragraph **5.f.(1)**.

(3) Instructions for continued performance applicable to the non-TSO function(s) described in paragraph **5.f.(1).**

(4) Interface requirements and applicable installation test procedures to ensure compliance with the performance data defined in paragraph **5.f.(1).**

(5) Test plans, analysis and results, as appropriate, to verify that performance of the hosting TSO article is not affected by the non-TSO function(s).

(6) Test plans, analysis and results, as appropriate, to verify the function and performance of the non-TSO function(s) as described in paragraph **5.f.(1).**

g. The quality system description required by 14 CFR § 21.607, including functional test specifications. The quality system should ensure that you will detect any change to the approved design that could adversely affect compliance with the TSO MPS, and reject the article accordingly. (Not required for LODA applicants.)

h. Material and process specifications list.

i. List of all drawings and processes (including revision level) that define the article's design.

j. Manufacturer's TSO qualification report showing results of testing accomplished according to paragraph **3.c** of this TSO.

6. MANUFACTURER DATA REQUIREMENTS

Besides the data given directly to the responsible ACO, have the following technical data available for review by the responsible ACO:

a. Functional qualification specifications for qualifying each production article to ensure compliance with this TSO.

b. Equipment calibration procedures.

c. Schematic drawings.

d. Wiring diagrams.

e. Material and process specifications.

f. The results of the environmental qualification tests conducted according to paragraph **3.d** of this TSO.

g. If the article includes software, the appropriate documentation defined in RTCA/DO-178B, *Process Objectives and Outputs by Software Level*, including all data supporting the applicable objectives in RTCA/DO-178B *Annex A*,

h. If the article contains non-TSO function(s), you must also make available items **6.a** through **6.h** as they pertain to the non-TSO function(s).

7. FURNISHED DATA REQUIREMENTS

a. If furnishing one or more articles manufactured under this TSO to one entity (such as an operator or repair station), provide one copy or on-line access to the data in paragraphs **5.a** and **5.b** of this TSO.

b. If the article contains declared non-TSO function(s), include one copy of the data in paragraphs **5.f.(1)** through **5.f.(4).**

c.

8. HOW TO GET REFERENCED DOCUMENTS

a. EUROCAE Documents: Order EUROCAE documents by calling Tel : +33 1 40 92 79 30 / Fax : +33 1 46 55 62 65 or e-mailing eurocae@eurocae.net. EUROCAE documents can also be downloaded by going to http://boutique.eurocae.net/catalog/

b. EUROCONTROL Documents: EUROCONTROL, STA/R/460/0001/1, *Study to Address the Detection and Recognition of Light Aircraft in the Current and Future ATM Environment, Issue 1.0, Final Report*, dated 31 March 2005

c. FAA Documents**:** You can find a current list of technical standard orders and Advisory Circulars on the FAA Internet website Regulatory and Guidance Library at http://rgl.faa.gov/. You will also find the TSO Index of Articles at the same site.

d. FCC Documents: Federal Communication Commission document OET Bulletin 65 Ed 97-01, *Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields* Is available on the internet at: http://transition.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet65/oet65.pdf

e. RTCA Documents: Order RTCA documents from RTCA Inc., 1150 18th Street NW, Suite 910, Washington, D.C. 20036. Telephone (202) 833-9339, fax (202) 833-9434. You can also order copies online at www.rtca.org

f. US CFR Documents: Order copies of 14 CFR parts 21, 45 and 91 from the Superintendent of Documents, Government Printing Office, P.O. Box 979050, St. Louis, MO 63197. Telephone (202) 512-1800, fax (202) 512-2250. You can also order copies online at www.access.gpo.gov. Select "Access," then "Online Bookstore." Select "Aviation," then "Code of Federal Regulations." You can also download a copy here: http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&rgn=div5&view=text&node=14:2.0.1.3.10&idno=14

g. UK Public Health Documents Public Health England document HPA-RPD-031, *Exposure to EMFs from Lightweight Aviation Transponders*, dated September 2007, ISBN 978-0-85951-605-1, can be obtained on line by searching the internet or going to: http://www.hpa.org.uk/Publications/Radiation/HPARPDSeriesReports/HpaRpd031/

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Appendix 1. Low Power Surveillance Equipment Requirements

A1. Requirements Introduction

A1.1. The intent of an LPSE device is to increase safety within the National Air Space (NAS) by encouraging the voluntary equipage of a low cost, compact, easy to install device that will allow other aircraft equipped with collision avoidance systems and traffic advisory systems to track and display the LPSE aircraft. LPSE devices are intended to be used on aircraft that are exempted from carrying a transponder or Automatic Dependent Surveillance - Broadcast (ADS-B) equipment per, such as gliders, balloons and aircraft without electrical systems. LPSE devices do not meet the transponder requirements defined in 14 CFR § 91.215 (b), and 14 CFR § 91.225 (b). LPSE will allow these exempted aircraft to be visible to other aircraft equipped with:

- Traffic Advisory System (TAS) as defined in TSO-C147
- Traffic Alert and Collision Avoidance System I (TCAS I) as defined in TSO-C118
- Traffic Alert and Collision Avoidance System II, (TCAS II), as defined in TSO-C119c
- Aircraft equipped with TCAS II hybrid surveillance as defined in TSO-C119c and
- Aircraft with ADS-B In capability as defined in TSO-C154c, TSO-C166b, and TSO-C195a

A1.2. Requirements

A1.2.1. LPSE requirements are derived from existing transponder and ADS-B requirements. Generally, the requirements herein are reduced from the full capability in the reference documents. The requirements outlined here will allow the equipment user the capability to be seen by other aircraft equipped with traffic advisory systems utilizing 1030 and 1090 MHz. A designer building equipment to meet this TSO may decide to incorporate more capability than what is outlined in this TSO as long as it meets the Minimum Operational Standards (MOPS) outlined in the referenced documents.

A1.2.2 Table 1 provides notes in italics and parenthesis explaining how to read the tables that modify the text in the source documents.

(Source document reference)	Modified text for this TSO
(This is a copy of the original text from the source document. Note material to be deleted from this original text is marked with ~~strikethrough formatting~~.)	*(This is the requirement for this TSO. Modifications to the source text are marked in **bold and underlined** to assist in identifying changes)*

Table 1 (Source document reference) (type of change)

A1.2.3. Transponder Function Requirements

A1.2.3.1. The surveillance transponder function must meet the Minimum Performance Standards (MPS) qualification and documentation requirements in RTCA document DO-181E,

section 1.4.5 and section 2, for a Level 2, Class 2, transponder. SI capability is not required on LPSE, unless Mode S All-Call capability is provided. Transponder capabilities are modified with the following exceptions:

A1.2.3.2. Interrogation Acceptance Protocol Changes (All-Call reply capability)

A1.2.3.2.1. The transponder All-Call interrogation reply acceptance requirements are reduced to reply only to ATCRBS Mode C (P1-P3) interrogations. The purpose is to reduce the reply rate of LPSE while maintaining TCAS I and TAS interoperability. To support this, the following changes have been made to RTCA/DO-181E.

A1.2.3.2.2. RTCA/DO-181E, section 2.2.18.2.2 b, Interrogation Acceptance Protocol (Figure 2-12) is amended as shown in Table 2.

DO-181E text	Modified text for this TSO
All-Call Address – If the address extracted from the received interrogation consists of 24 ONEs and UF=11, the transmission is a Mode S-Only All-Call and the received interrogation shall **be** accepted ~~according to "i" below unless the lockout protocol is in effect. Mode S-Only All-Call shall not be accepted (no replies) when in the on-the-ground state (consistent with the CA, VS and FS fields)~~	All-Call Address – If the address extracted from the received interrogation consists of 24 ONEs and UF=11, the transmission is a Mode S-Only All-Call and the received interrogation shall **not** be accepted.

Table 2 DO-181E section 2.2.18.2.2 b amendment

A1.2.3.2.3. RTCA/DO-181E, section 2.2.18.2.2 c, Interrogation Acceptance Protocol (Figure 2-12) is amended as shown in Table 3.

DO-181E text	Modified text for this TSO
ATCRBS/Mode S All-Call – An ATCRBS/Mode S All-Call interrogation (1.6 microseconds P_4) shall **be** accepted ~~unless the T_D timer is running or side lobe suppression is in effect or when in the "on-the-ground" state (consistent with the CA, VS and FS fields)~~.	ATCRBS/Mode S All-Call – An ATCRBS/Mode S All-Call interrogation (1.6 microseconds P_4) shall **not** be accepted.

Table 3 DO-181E section 2.2.18.2.2 c amendment

A1.2.3.2.4. Two new sections are added here to explicitly define interrogation acceptance criteria for LPSE.

A1.2.3.2.4.1. RTCA/DO-181E, section 2.2.18.2.2 L, Interrogation Acceptance Protocol (Figure 2-12) is added as shown in Table 4.

DO-181E text	Modified text for this TSO
None	ATCRBS Mode A Rejection – ATCRBS Mode A interrogations (P1-P3 spacing 8 microseconds) shall not be accepted.

Table 4 DO-181E section 2.2.18.2.2 L addition

A1.2.3.2.4.2. RTCA/DO-181E, section 2.2.18.2.2 m, Interrogation Acceptance Protocol (Figure 2-12) is added to as shown in Table 5. This change reduces the range at which addressed Mode S ground interrogations would be replied to. The intent is to reduce the reply rate of the LPSE. Sensitivity to TCAS interrogations are not affected.

DO-181E text	Modified text for this TSO
None	Ground-to-Air Mode S Acceptance – Mode S interrogations, excluding UF0 and UF16 may be accepted at the Mode S MTL (§2.2.2.4 b) +3dB ± 1dB.

Table 5 DO-181E section 2.2.18.2.2 m addition

A1.2.3.3. Reply Rate Capability Changes

A1.2.3.3.1. This section reduces the minimum reply rate capability of the LPSE consistent with the interrogation acceptance.

A1.2.3.3.2. The following rationale describes how the modified reply rates were chosen. The worst case Mode C interrogation count in a 100 millisecond interval from one ATCRBS radar is approximately 14 interrogations. Four ATCRBS radar overlapping beam dwells in a second is approximately 53 Mode C interrogations. The Mode C interrogation acceptance rate from 10 TCAS I nearby units is approximately 15 interrogations/second. This represents a total demand on the LPSE of 68 Mode C replies/second in this illustration.

A1.2.3.3.3. The worst case Mode S reply rate is primarily derived from the expected interrogation pattern of a set of 50 nearby TCAS II units all equipped with hybrid surveillance. The radar load from only roll-call interrogations would be small and would require networked sensors, otherwise the Mode S ground interrogation acceptance rate from radar systems would be zero.

A1.2.3.3.4. Based on these values, RTCA/DO-181E section “2.2.3.4 Reply Rate Capability” is changed as follows:

A1.2.3.3.4.1. RTCA/DO-181E, section 2.2.3.4.1 a, ATCRBS Reply Rate Capability is amended as shown in Table 6.

DO-181E text	Modified text for this TSO
The transponder **s**hall be able to continuously generate at least **500** ATCRBS 15-pulse replies per second.	The transponder shall be able to continuously generate at least **100** ATCRBS 15-pulse replies per second.

Table 6 DO-181E section 2.2.3.4.1 a amendment

A1.2.3.3.4.2. RTCA/DO-181E, section 2.2.3.4.1 c, ATCRBS Reply Rate Capability is amended as shown in Table 7.

DO-181E text	Modified text for this TSO
For Class 2 equipment, the transponder **s**hall be capable of a peak reply rate of **1000** ATCRBS 15-pulse replies per second for a duration of 100 milliseconds.	For Class 2 equipment, the transponder **s**hall be capable of a peak reply rate of **150** ATCRBS 15-pulse replies per second for a duration of 100 milliseconds.

Table 7 DO-181E section 2.2.3.4.1 c added

A1.2.3.3.4.3. RTCA/DO-181E, section 2.2.3.4.2 a, Mode S Reply Rate Capability is amended as shown in Table 8.

DO-181E text	Modified text for this TSO
A transponder equipped for only short Mode S downlink formats (DF), shall have the following minimum reply rate capabilities: **50** Mode S replies in any 1-second interval. **18** Mode S replies in a 100-millisecond interval. **8** Mode S replies in a 25-millisecond interval. **4** Mode S replies in a l.6-millisecond interval.	A transponder equipped for only short Mode S downlink formats (DF), **s**hall have the following minimum reply rate capabilities: **29** Mode S replies in any 1-second interval. **10** Mode S replies in a 100-millisecond interval. **5** Mode S replies in a 25-millisecond interval. **3** Mode S replies in a l.6-millisecond interval.

Table 8 DO-181E section 2.2.3.4.2 a amendment

A1.2.3.3.4.4. RTCA/DO-181E, section 2.2.3.4.2 b, Mode S Reply Rate Capability is amended as shown in Table 9.

DO-181E text	Modified text for this TSO
A transponder equipped for long Mode S reply formats **s**hall be able to transmit as long replies: At least **16** of the **50** Mode S replies in any 1-second interval. At least **6** of the **18** Mode S replies in a 100 millisecond interval. At least **4** of the **8** Mode S replies in a 25 millisecond interval. At least 2 of the **4** Mode S replies in a l.6 millisecond interval.	A transponder equipped for long Mode S reply formats shall be able to transmit as long replies: At least **10** of the **29** Mode S replies in any 1-second interval. At least **4** of the **10** Mode S replies in a 100 millisecond interval. At least **3** of the **5** Mode S replies in a 25 millisecond interval. At least 2 of the **3** Mode S replies in a l.6 millisecond interval.

Table 9 DO-181E section 2.2.3.4.2 b amendment

A1.2.3.4. Reply Rate Limiting Changes

A1.2.3.4.1. The modifications in this section address reply rate limiting for ATCRBS and Mode S reply rates consistent with previous section.

A1.2.3.4.2. RTCA/DO-181E, section 2.2.7.3.1, ATCRBS Reply Rate Limiting is amended as shown in Table 10.

DO-181E text	Modified text for this TSO
A sensitivity-reduction reply rate limit shall be incorporated in the transponder for ATCRBS replies. The limit shall be capable of being adjusted between **500** continuous ATCRBS ~~Mode A and~~ Mode C replies per second and the maximum continuous rate of which the transponder is capable, or **2000** replies per second, whichever is less, without regard to the number of pulses in each reply. Sensitivity reduction shall apply only to the receipt of ATCRBS~~, ATCRBS/Mode S All-Call, and ATCRBS-Only All-Call~~ interrogations.	A sensitivity-reduction reply rate limit shall be incorporated in the transponder for ATCRBS replies. The limit **s**hall be capable of being adjusted between **100** continuous ATCRBS Mode C replies per second and the maximum continuous rate of which the transponder is capable, or **200** replies per second, whichever is less, without regard to the number of pulses in each reply. Sensitivity reduction shall apply only to the receipt of ATCRBS interrogations.

Table 10 DO-181E section 2.2.7.3.1 amendment

A1.2.3.4.3. RTCA/DO-181E, section 2.2.7.3.2, Mode S Reply Limiting is amended as shown in Table 11.

DO-181E text	Modified text for this TSO
~~If~~ a reply rate limiting device ~~is~~ provided for Mode S replies, ~~it~~ shall permit at least the reply rates required in §2.2.3.4.2. A limiting device ~~may~~ be used to protect the transponder from accidental over-interrogation.	A reply rate limiting device provided for Mode S replies, **shall** permit at least the reply rates required in §2.2.3.4.2. A limiting device may be used to protect the transponder from accidental over-interrogation.

Table 11 DO-181E section 2.2.7.3.2 amendment

A1.2.3.5. Flight Crew Control Functions Changes

A1.2.3.5.1. A cost factor in any device is the control and display functions to interface with the human operator. LPSE display and control requirements are a subset of those required for transponders. Some user controls are allowed via an external device prior to flight (e.g. a laptop). If the system is powered by batteries, display of available battery life is recommended. Table 12 provides an overview of flight crew control functions.

Operation mode	Controls	Required Indicators
In flight (i.e. control head)	Power, Emergency (optional) IDENT (optional)	Power on, Transponder Fail ADS-B Fail
Non flight (optional in flight) (i.e. laptop)	Set 4096 code, Set Flight ID	Display of 4096 code, Display of Flight ID
Maintenance actions (allowed in non flight conditions only)	Set ICAO 24 bit aircraft address, Set implementation specific configuration	Display of ICAO 24 bit aircraft address, Display of implementation specific configuration.

Table 12 Summary of Control and Indication Requirements by Operation Mode

A1.2.3.5.2. RTCA/DO-181E, section 2.1.7, Flight Crew Control Functions, is amended as shown in Table 13.

DO-181E text	Modified text for this TSO
The following functions shall be provided	The following functions shall be provided **as indicated in items a-f.**

Table 13 DO-181E section 2.1.7 amendment

A1.2.3.5.3. RTCA/DO-181E, section 2.1.7 a, Flight Crew Control Functions, is amended as shown in Table 14.

DO-181E text	Modified text for this TSO
A means of selecting each of the ATCRBS 4096 reply code~~s, and of~~ indicating the code selected.	A means of selecting **and displaying** the ATCRBS 4096 code **on the ground shall be required. A means of selecting and displaying the ATCRBS 4096 code in flight is not required.**

Table 14 DO-181E section 2.1.7 a amendment

A1.2.3.5.4. RTCA/DO-181E, section 2.1.7 b, Flight Crew Control Functions, is amended as shown in Table 15.

DO-181E text	Modified text for this TSO
A means of selecting the air/ground state: 1) An automatic means ~~shall be the only acceptable means~~ to determine the air/ground state. 2) If an automatic means is not ~~available~~, the transponder shall ensure that the air/ground state is Airborne	A means of selecting the air/ground state: 1) An automatic means to determine the air/ground state **is recommended**. 2) If an automatic means is not **implemented**, the transponder shall ensure that the air/ground state is Airborne.

Table 15 DO-181E section 2.1.7 b amendment

A1.2.3.5.5. RTCA/DO-181E, section 2.1.7 c, Flight Crew Control Functions, is not required as shown in Table 16.

DO-181E text	Modified text for this TSO
A means of selecting the condition in which all transponder functions, other than transmission on the reply frequency and associated self-testing, are operational (i.e., the Standby condition). Return to normal operation from this condition shall be possible within five seconds.	A means of selecting the condition in which all transponder functions, other than transmission on the reply frequency and associated self-testing, are operational (i.e., the Standby condition**) is not required**. **However if provided,** return to normal operation from Standby condition shall be possible within five seconds."

Table 16 DO-181E section. 2.1.7 c amendment

A1.2.3.5.6. RTCA/DO-181E, section 2.1.7 d, Flight Crew Control Functions, is not required as shown in Table 17.

DO-181E text	Modified text for this TSO
A means of initiating the IDENT (SPI) feature.	A means of initiating the IDENT (SPI) feature **is recommended but not required**.

Table 17 DO-181E section 2.1.7 d amendment

A1.2.4. Altitude Source Function Requirements

A1.2.4.1. The altitude source function must meet the requirements of TSO-C88b, *Automatic Pressure Altitude Reporting Code-Generating Equipment*, dated February 6, 2007. It is recommended that the altitude source provide 25 foot or better resolution.

A1.2.5 ADS-B Out Function Requirements

A1.2.5.1 The ADS-B Out function must be 1090 Extended Squitter (ES) Out, to allow support of TCAS hybrid surveillance. The 1090ES Out function must meet the Minimum Performance Standards (MPS) qualification and documentation requirements in RTCA DO-260B, *Minimum Operational Performance Standards for 1090 MHz Automatic Dependent Surveillance – Broadcast (ADS-B) and Traffic Information Services – Broadcast (TIS-B)*, dated Dec 2, 2009, section 2, Class B0 ADS-B Out transmitter with the following exceptions:

A1.2.5.2. For all implemented extended squitters, the transmission rate shall be half that specified in section 2.2.3.3 in RTCA DO-260B.

A1.2.5.3. If the altitude rate is greater than 500 fpm, the airborne position squitters shall be transmitted at the rate specified in RTCA DO-260B, section 2.3.2.2.8 for the next 18 ±1.0 seconds.

A1.2.5.4. RTCA DO-260B, Paragraph 2.2.2.1 c, Mode S Transponder-Based Transmitters is amended as shown in Table 18:

DO-260B text	Modified text for this TSO
If the ADS-B transmitter is based on Mode S transponders, then for transponder functions it shall comply with RTCA DO-181D (EUROCAE ED-73C) for each class of transponder specified in the latest version of FAA TSO C112 (ETSO 2C112)	If the ADS-B transmitter is based on Mode S transponders, then for transponder functions it shall comply with RTCA DO-181**E** (EUROCAE ED-73**D**) for each class of transponder specified in the latest version of FAA TSO C112 (ETSO 2C112), except where modified by **Appendix 1** of this TSO.

Table 18 DO-181E section 2.2.2.1 c amendment

A1.2.5.5. The output power shall be specified in RTCA DO-260B, section 2.2.2.2.10.1 for Class A0 and B0 equipment. The RF Peak Output power shall be at least 18.5 dBW (70 watts).

A1.2.5.6. The System Design Assurance (SDA) OM code subfield in the Aircraft Operational Status Message,(reference RTCA DO-260B, section 2.2.3.2.7.2.4.6), shall be set to 1. The probability of an undetected fault causing transmission of false or misleading information shall be $\leq 1x10^{-3}$.

A1.2.5.7. O**ptional ADS-B Out Capabilities**

A1.2.5.7.1. The RTCA DO-260B capabilities listed in Table 19 are not required by the LPSE.

RTCA DO-260B Paragraph number	Paragraph title
2.1.5.1	Optional Extended Squitter Inhibit
2.2.3.2.1.4	"AF" Field (used in DF=19)
2.2.3.2.4	ADS-B Surface Position Messages
2.2.3.2.6.2	ADS-B Airborne Velocity Message - Subtype=2
2.2.3.2.6.3	ADS-B Airborne Velocity Message - Subtype=3
2.2.3.2.6.4	ADS-B Airborne Velocity Message - Subtype=4
2.2.3.2.6.5	ADS-B Airborne Velocity Messages - Subtypes "5, 6, & 7"
2.2.3.2.7.1.3	Target State and Status Message (Subtype=1)
2.2.3.2.7.2.4.3	IDENT Switch
2.2.3.2.7.2.4.7	GPS Antenna Offset OM Code Subfield in Aircraft Operational Status Messages
2.2.3.2.7.2.11	Aircraft/Vehicle Length and Width Code Subfield in Aircraft Operational Status Messages
2.2.3.2.7.4	Surface System Status Messages with TYPE Code=24
2.2.3.2.7.8.1.1	Emergency/Priority Status
2.2.3.2.7.8.1.2	4096 code
2.2.3.3.1.4.4	TYPE Code=23 (TEST) ADS-B Event- Driven Message Broadcast Rate
2.2.3.3.2.3	ADS-B Surface Position Message Broadcast Rate
2.2.3.3.2.6.1	ADS-B Target State and Status Message Broadcast Rates

Table 19 DO-260B optional capabilities

A1.2.5.8. 1090ES TCAS Resolution Advisory (RA) Broadcast Message (Subtype=2), noted in section 2.2.3.2.7.8.2, shall not be installed on LPSE equipment.

A1.2.6. GNSS Position Source Function Requirements

A1.2.6.1. While an aviation grade GNSS position source that meets a published TSO is desired, it is not required. The system must be designed such that it transmits NACp≥1 and NACv≥1. NIC and SIL may be set to zero or nonzero based on the capabilities of the GNSS engine. The system must be capable of detecting signal in space errors and prevent the LPSE from transmitting false or misleading information. To support this, the GNSS position source must be screened using the test procedures in **Appendix 2**. The position source must reject the injected errors and either drop the affected pseudorange measurement from the solution, Fault Detection and Exclusion (FDE), or fail the solution. There is no requirement for commercial sensors to work through single satellite failures. They must detect them and fail the solution at a minimum to be acceptable for use with LPSE. Thus the potential for false and misleading data is detected and the system does not transmit it.

A1.2.6.2. LPSE shall output a NIC appropriate to the integrity level. LPSE equipment is allowed to report NIC=0. LPSE designs may set NIC non-zero if the GNSS sensor can be shown to provide integrity consistent with the definitions in 14 CFR § 91.227 and RTCA DO-260B. A Receiver Autonomous Integrity Monitor (RAIM) algorithm is an acceptable method to determine the NIC value of the system. Perform the testing as described in **Appendix 2,** section A2.2.6.2. of this TSO to verify the NIC integrity value output is appropriate. Equipment that cannot pass this test shall output a NIC=0. If the test shows that the equipment has the ability to accurately report NIC>0 the SIL should be set to 3 otherwise it must set SIL to zero.

A1.2.6.3. LPSE shall be capable of detecting a step error. Step error detection testing is outlined in **Appendix 2,** section A2.2.6.3 of this TSO. A GNSS receiver not capable of detecting step errors shall not used.

A1.2.6.4. LPSE shall be capable of detecting a ramp error. Ramp error detection testing is outlined in **Appendix 2,** section A2.2.6.4 of this TSO. A GNSS receiver not capable of detecting ramp errors shall not used.

A1.2.6.5. LPSE should be capable of detecting errors due to interference, and stop transmitting false or misleading information (e.g. set NACp, Latitude and Longitude to 0) when errors due to interference are detected. Testing to determine the interference capability of a GPS system is outlined in **Appendix 2**, section A2.2.6.5 of this TSO.

A1.2.6.6. LPSE equipment shall be capable of outputting a non-zero NACp. If NACp cannot be determined, NACp=0 shall be output. Performing accuracy testing to determine this is outlined in **Appendix 2,** section A2.2.6.1.5 of this TSO.

A1.2.6.7. LPSE equipment should be capable of outputting a non- zero NACv. If NACv cannot be determined, NACv=0 shall be output. Performing accuracy testing to determine this is outlined in **Appendix 2,** section A2.2.6.7 of the TSO.

A1.2.7. Antenna Function Requirements

A1.2.7.1. The general requirements for antennas are specified in the associated TSO and MOPS documents for equipment referenced in this TSO. However the LPSE may benefit significantly in installation costs from implementations where the antenna is integrated in the LPSE equipment.

A1.2.7.2. Because LPSE may be installed on a RF transparent fuselage near a pilot or passenger, or in a cockpit in close proximity to a pilot or passenger, consideration must be given to antenna placement to ensure it does not pose a hazard to humans or combustible materials. Manufacturers must provide installation guidance describing the minimum safe distance the antenna can be to the nearest human body or if applicable, combustible material. Appendix 3 of this TSO provides a more in depth discussion of this subject based on FCC and European documents.

A1.2.7.3. Antennas may be installed internally on aircraft that are transparent to radar. An internal antenna may not be appropriate on aircraft with metal hulls or radar opaque surfaces. If an antenna is installed internally, testing will need to be conducted to ensure the LPSE system

is not negatively impacted and installation guidance will need to accompany the unit to ensure the system is properly fitted to the aircraft.

A1.2.8. Form factor and power

A1.2.8.1. An ideal implementation of the LPSE would be a single integrated unit with minimal connections to the airframe, such as; mechanical mounting, power, and static air source. Where the equipment might be shared between multiple airframes, the mechanical mounting could incorporate an airframe specific configuration module (containing such items as the ICAO 24 bit aircraft address), and be designed such that no tools are required to remove or install the LPSE.

A1.2.8.2. Low power consumption design is important. Designs specifically intended for long term battery operation are ideal. If the LPSE unit is battery powered, it must meet the applicable battery TSO, FAA TSO-C142a *Non-Rechargeable Lithium Cells and Batteries*, TSO-C173 *Nickel-Cadmium and Lead Acid Batteries*, or TSO-C179a *Permanently Installed Rechargeable Lithium Cells, Batteries and Battery Systems*.

Appendix 2. Test Requirements

A2. Testing Introduction

A2.1. This appendix provides an acceptable means to verify the major functions of the LPSE.

A2.2. The LPSE is not intended to accept and reply to any UF=11 All-Call interrogation. RTCA DO-181E tests like 2.4.2.1 Step 6 that use the Mode S Only All-Call interrogation (UF=11) will need to use a different interrogation, such as an UF=0 interrogation.

A2.2. Testing Requirements

A2.2.1. The tests defined here are derived from tests in the reference document or referenced in their entirety. These tests are one acceptable means to demonstrate the equipment meets the functional requirements defined in **Appendix 1** of this TSO. Functionality not modified by **Appendix 1** should be verified by the test outlined in the applicable standards, e.g. RTCA DO-181E.

A2.2.2. Table 20 provides notes in italics and parenthesis explaining how to read the tables that modify the text in the source documents.

(Source document reference)	Modified text for this TSO
(This is a copy of the original text from the source document. Material to be deleted from this original text is marked with ~~strikethrough formatting~~.)	*(This is the requirement for this TSO. Modifications to the source text are marked in **bold and underlined** to assist in identifying changes)*

Table 20 (Source document reference) (type of change)

A2.2.3. Testing of Transponder Function Requirements

A2.2.3.1. Testing of the transponder function of the LPSE should follow the tests outlined in RTCA, Inc. document RTCA/DO-181E, *Minimum Operational Performance Standards for Air Traffic Control Radar Beacon System/Mode Select (ATCRBS/Mode S) Airborne Equipment*, dated March 17, 2011, section 2.3, 2.4, and 2.5, with the following exceptions:

A2.2.3.2. Testing of Interrogation Acceptance Protocol Changes (All-Call reply capability)

A2.2.3.2.1. Except where noted here, testing of the Interrogation Acceptance Protocol capability should follow that called out in RTCA DO-181E. Testing of the Interrogation Acceptance Protocol capability should be modified from those called out in RTCA DO-181E to meet the changes made in **Appendix 1** above.

A2.2.3.2.2. Testing should verify that changes made to RTCA/DO-181E, section 2.2.18.2.2 b have been properly incorporated per section A1.2.3.2.2. Testing outlined in

DO-181E, section 2.5.4.2 should verify that if the address extracted from the received interrogation consists of 24 ONEs and UF=11, the received interrogation is **not** accepted.

A2.2.3.2.3. Testing should verify that changes made to RTCA/DO-181E, section 2.2.18.2.2 c, have been properly incorporated per section A1.2.3.2.3. Testing outlined in DO-181E, section 2.5.4.2 should verify that an ATCRBS/Mode S All-Call interrogation (1.6 microseconds P_4) is **not** accepted.

A2.2.3.2.4. Testing should verify that changes made to RTCA/DO-181E, the adding of section 2.2.18.2.2 L, has been properly incorporated per section A1.2.3.2.4.1. Testing outlined in DO-181E, section 2.5.4.2 should verify that ATCRBS Mode A interrogations (P1-P3 spacing 8 microseconds) is **not** accepted.

A2.2.3.2.5. Testing should verify that changes made to RTCA/DO-181E, the adding of section 2.2.18.2.2 m, has been properly incorporated per section A1.2.3.2.4.2. Verify the requirement added by this TSO, in section A1.2.3.2.4.2, by adding this to the test procedure in RTCA/DO-181E, section 2.4.2.1. step 6:

Ground-to-Air Mode S acceptance If the optional UF based differential Mode S acceptance in implemented, using the procedures in §2.4.2.1 step 6 interrogate transponder with Mode S formats UF=0, 16, 4, 5, 20, 21.

Verify The equivalent Mode S MTL for UF=4, 5,20, 21 is +3dB ±1 dB above the Mode S MTL for UF=0, 16

A2.2.3.3. Testing of Reply Rate Capability

A2.2.3.3.1. Testing should verify that changes made to RTCA/DO-181E, section 2.2.3.4.1.a, have been properly incorporated per section A1.2.3.3.4.1. Testing outlined in DO-181E, section 2.3.2.2.3 step 1 should verify that the transponder be able to continuously generate at least 100 ATCRBS 15-pulse replies per second.

A2.2.3.3.2. Testing should verify that changes made to RTCA/DO-181E, section 2.2.3.4.1 c, have been properly incorporated per section A1.2.3.3.4.2. Testing outlined in DO-181E, section 2.3.2.2.3 step 3 should verify that the transponder **s**hall be capable of a peak reply rate of 150 ATCRBS 15-pulse replies per second for a duration of 100 milliseconds.

A2.2.3.3.3. Testing should verify that changes made to RTCA/DO-181E, section 2.2.3.2.4.2.a have been properly incorporated per section A1.2.3.3.4.3. Testing outlined in DO-181E, section 2.3.2.2.3 step 2 should verify that the transponder provide at least 29 short Mode S replies in any 1-second interval.

A2.2.3.3.4. Testing should verify that changes made to RTCA/DO-181E, section 2.2.3.2.4.2.a have been properly incorporated per section A1.2.3.3.4.3. Testing outlined in DO-181E, section 2.3.2.2.3 step 3 should verify that the transponder provide at least 10 short Mode S replies in a 100-millisecond interval.

A2.2.3.3.5. Testing should verify that changes made to RTCA/DO-181E, section 2.2.3.2.4.2.a have been properly incorporated per section A1.2.3.3.4.3. Testing outlined in DO-181E, section 2.3.2.2.3 step 4 should verify that the transponder provide at least 5 short Mode S replies in a 25-millisecond interval.

A2.2.3.3.6. Testing should verify that changes made to RTCA/DO-181E, section 2.2.3.2.4.2.a have been properly incorporated per section A1.2.3.3.4.3. Testing outlined in DO-181E, section 2.3.2.2.3 step 5 should verify that the transponder provide at least 3 short Mode S replies in a l.6-millisecond interval.

A2.2.3.3.7. Testing should verify that changes made to RTCA/DO-181E, section 2.2.3.2.4.2.b have been properly incorporated per section A1.2.3.3.4.4. Testing outlined in DO-181E, section 2.3.2.2.3 step 2 should verify that the transponder provide at least 10 of the 29 Mode S replies as long format replies in any 1-second interval.

A2.2.3.3.8. Testing should verify that changes made to RTCA/DO-181E, section 2.2.3.2.4.2.b have been properly incorporated per section A1.2.3.3.4.4. Testing outlined in DO-181E, section 2.3.2.2.3 step 3 should verify that the transponder provide at least 4 of the 10 Mode S replies as long format replies in a 100-millisecond interval.

A2.2.3.3.9. Testing should verify that changes made to RTCA/DO-181E, section 2.2.3.2.4.2.b have been properly incorporated per section A1.2.3.3.4.4. Testing outlined in DO-181E, section 2.3.2.2.3 step 4 should verify that the transponder provide at least 3 of the 5 Mode S replies as long format replies in a 25-millisecond interval.

A2.2.3.3.10. Testing should verify that changes made to RTCA/DO-181E, section 2.2.3.2.4.2.b have been properly incorporated per section A1.2.3.3.4.4. Testing outlined in DO-181E, section 2.3.2.2.3 step 5 should verify that the transponder provide at least 2 of the 3 Mode S replies as long format replies in a l.6-millisecond interval.

A2.2.3.4. Testing of Reply Rate Limiting

A2.2.3.4.1. Testing should verify that changes made to RTCA/DO-181E, section 2.2.7.3.1, noted in section A1.2.3.4.2, have been properly incorporated. Testing outlined DO-181E section 2.4.2.2.5 step 1 should be performed to verify the unit does not reply to Mode A interrogations.

A2.2.3.4.2. Testing should verify that changes made to RTCA/DO-181E, section 2.2.7.3.1, noted in section A1.2.3.4.2, have been properly incorporated. Testing outlined in DO-181E section 2.4.2.2.5 step 1 should be performed to verify the unit is capable of between 100 continuous ATCRBS Mode C replies per second and the maximum continuous rate of which the transponder is capable, or 200 replies per second, whichever is less, without regard to the number of pulses in each reply. Sensitivity reduction shall apply only to the receipt of ATCRBS interrogations.

A2.2.3.4.3. A reply rate limiting device provided for Mode S replies, shall permit at least the reply rates required in RTCA/DO-181E section 2.2.3.4.2. A limiting device may be used to protect the transponder from accidental over interrogation.

A2.2.3.5. Testing of Flight Crew Control Functions

A2.2.3.5.1. Testing should verify that changes made to RTCA/DO-181E, section 2.1.7.a, have been properly incorporated. Testing should verify that a means of selecting and displaying the ATCRBS 4096 code on the ground is provided per section A1.2.3.5.3. If a means of

selecting and displaying the ATCRBS 4096 code in flight is provided it should be shown to function correctly per RTCA/DO-181E section 2.5.4.11.

A2.2.3.5.2. Testing should verify that changes made to RTCA/DO-181E, section 2.1.7.b, with regard to air-ground state, have been properly incorporated per A1.2.3.5.4.

A2.2.3.5.2.1. Aircraft without a means to automatically determine air/ground state, must verify that the air/ground state is set to in-the- air, by performing the test outlined in RTCA/DO-181E 2.5.4.3.b. Test results should verify the aircraft reports in-the-air at all times.

A2.2.3.5.2.2. Aircraft with an automatic means to determine the air/ground state, must verify that the air/ground state is set properly. Perform the test outlined in RTCA/DO-181E 2.5.4.3.b. Test results should verify the aircraft reports in-the-air when in the air, and on-the-ground when on the ground.

A2.2.3.5.3. Testing should verify that changes made to RTCA/DO-181E, section 2.1.7.c, as amended by A1.2.3.5.5, have been properly incorporated. If a means of selecting the Standby condition is provided, testing should show return to normal operation from Standby condition is within five seconds.

A2.2.3.5.4. Testing should verify that changes made to RTCA/DO-181E, section 2.1.7.d, as amended by A1.2.3.5.6, have been properly incorporated. If a means of initiating the IDENT (SPI) feature is installed, testing should show it functions properly per RTCA/DO-181E section 2.3.2.11.2.

A2.2.4. Testing of Altitude Source Function Requirements

A2.2.4.1. Testing of the Altitude Source Function should follow that called out in TSO-C88b, *Automatic Pressure Altitude Reporting Code-Generating Equipment* dated February 06, 2007.

A2.2.5 Testing of ADS-B Out Function Requirements

A2.2.5.1. ADS-B testing should follow the tests outlined in RTCA, Inc. document RTCA DO-260B, *Minimum Operational Performance Standards for 1090 MHz Automatic Dependent Surveillance – Broadcast (ADS-B) and Traffic Information Services – Broadcast (TIS-B)*, dated Dec 2, 2009, section 2.3 and 2.4 with the following exceptions:

A2.2.5.2. Testing should verify the message transmission rate meets those noted in section 2.2.3.3 in RTCA DO-260B, as amended by section A1.2.5.2. Testing should verify ADS-B messages are broadcast at half the broadcast rate per DO-260B, section 2.3.2.2.8.

A2.2.5.3. Per A1.2.5.3, testing should verify that when the altitude rate is greater than +/- 500 fpm, verify the extended squitter containing altitude information are transmitted at the rate specified in RTCA/DO-260B, section 2.3.2.2, **and**;

A2.2.5.4. Per A1.2.5.3, testing should verify that after the altitude rate decreases to less than +/- 500 fpm, the extended squitters containing altitude information continue to be transmitted at the rate specified in RTCA DO-260B, section 2.3.2.2.8, for the next 18 ±1.0 seconds.

A2.2.5.5. Per section A1.2.5.5, testing should verify that the RF Peak Output power is at least 18.5 dBW (70 watts) per 2.3.2.2.6 in DO-260B.

A2.2.5.6. Per section A1.2.5.6, testing should verify the System Design Assurance (SDA) OM code subfield in the Aircraft Operational Status Message, is set to 1 per DO-260B section 2.4.3.2.7.2.4.6.

A2.2.5.7. Testing of Optional ADS-B Out Capabilities

A2.2.5.7.1. If the optional Extended Squitter Inhibit ADS-B function is included, per section A1.2.5.7.1, operate the ADS-B control to verify the system is inhibited when turned off, and works properly when turned on.

A2.2.5.7.2 If the optional "AF" Field (used in DF=19) ADS-B function is included, per section A1.2.5.7.1, it must be tested per RTCA DO-260B section 2.4.3.2.1.4 to verify it performs its intended function.

A2.2.5.7.3 If the optional ADS-B Surface Position Messages function is included, per section A1.2.5.7.1, it must be tested per RTCA DO-260B section 2.4.3.2.1.2.2 to verify it performs its intended function.

A2.2.5.7.4 If the optional ADS-B Airborne Velocity Message - Subtype=2 function is included, per section A1.2.5.7.1, it must be tested per RTCA DO-260B section 2.4.3.2.6.2 to verify it performs its intended function.

A2.2.5.7.5 If the optional ADS-B Airborne Velocity Message - Subtype=3 function is included, per section A1.2.5.7.1, it must be tested per RTCA DO-260B section 2.4.3.2.6.3 to verify it performs its intended function.

A2.2.5.7.6 If the optional ADS-B Airborne Velocity Message - Subtype=4 function is included, per section A1.2.5.7.1, it must be tested per RTCA DO-260B section 2.4.3.2.6.4 to verify it performs its intended function.

A2.2.5.7.7 If the optional ADS-B Airborne Velocity Message - Subtype=5, 6, & 7 function is included, per section A1.2.5.7.1, it must be tested per RTCA DO-260B section 2.4.3.2.6.5 to verify it performs it's intended function.

A2.2.5.7.8 If the optional Target State and Status Message (Subtype=1) Format function is included, per section A1.2.5.7.1, it must be tested per RTCA DO-260B section 2.4.3.2.7.1.3.1 to verify it performs its intended function.

A2.2.5.7.9. If the optional pilot control functions for IDENT is included per A1.2.5.7.1, testing should verify proper transmission of this information in the appropriate extended squitters messages per RTCA DO-260B section 2.4.3.2.7.2.4.3.

A2.2.5.7.10 If the optional GPS Antenna Offset" OM Code Subfield in Aircraft Operational Status Messages function is included, per section A1.2.5.3.1, it must be tested per RTCA DO-260B section 2.4.3.2.7.2.4.7 to verify it performs it's intended function.

A2.2.5.7.11 If the optional Aircraft/Vehicle Length and Width Code" Subfield in Aircraft Operational Status Messages function is included, per section A1.2.5.7.1, it must be tested per RTCA DO-260B section 2.4.3.2.7.2.11 to verify it performs it's intended function.

A2.2.5.7.12 If the optional Surface System Status Messages with TYPE Code=24 function is included, per section A1.2.5.7.1, it must be tested per RTCA DO-260B section 2.4.3.2.7.4 to verify it performs its intended function.

A2.2.5.7.13. If the optional pilot control functions for Emergency/Priority Status are included per A1.2.5.7.1, testing should verify proper transmission of this information in the appropriate extended squitters messages per RTCA DO-260B section 2.4.3.2.7.8.1.1.

A2.2.5.7.14. If the optional pilot control functions for 4096 code are included per A1.2.5.7.1, testing should verify proper transmission of this information in the appropriate extended squitters messages per RTCA DO-260B section 2.4.3.2.7.8.1.2.

A2.2.5.7.15 If the optional TYPE Code=23 (TEST)" ADS-B Event- Driven Message Broadcast Rate function is included, per section A1.2.5.7.1, it must be tested per RTCA DO-260B section 2.4.3.3.1.4.4 to verify it performs it's intended function.

A2.2.5.7.16 If the optional ADS-B Surface Position Message Broadcast Rate function is included, per section A1.2.5.7.1, it must be tested per RTCA DO-260B section 2.4.3.3.2 to verify it performs its intended function.

A2.2.5.7.17 If the optional ADS-B Target State and Status Message Broadcast Rates function is included, per section A1.2.5.7.1, it must be tested per RTCA DO-260B section 2.4.3.3.2.4. to verify it performs it's intended function.

A2.2.6. Testing of Position Source Function Requirements

A2.2.6.1. When the design incorporates a GNSS receiver not compliant to a TSO, the following tests must be performed to establish the suitability of the position source for use in a LPSE. GNSS that are TSO compliant must use the test procedures referenced in the applicable TSO.

A2.2.6.2. If the GNSS receiver is capable of computing an integrity value per section A1.2.6.2, performing the Off-Line Fault Detection and Exclusion (FDE) tests found in RTCA DO-229D, change 1, section 2.5.9.3 is a suitable method for verifying the functionality. Equipment that cannot compute integrity shall output a NIC=0.

A2.2.6.3. The GNSS receiver must be capable of detecting a step error per A1.2.6.3. The step detector test outlined in section 2.5.3, in RTCA DO-229D change 1, shall be performed to verify capability of the equipment. The position system shall pass this test in order to meet this TSO. The position source must be able to detect the step error in this scenario. Record the size of the position error when the position source detected the step error. Record whether the position source failed the solution or excluded the failed satellite signal. A GNSS engine that cannot detect a step error shall not be used with LPSE equipment.

A2.2.6.4. The position source must be able to detect a ramp error per A1.2.6.4. The FDE tests found in RTCA DO-229D change 1, section 2.5.9.3 is a suitable method of determining if the GNSS engine is capable of detecting this type of error. Record the size of the error when the position source detected the error during testing. Also, record whether the position source failed the solution or excluded the failed satellite signal. A GNSS engine that cannot detect a ramp error shall not be used with LPSE equipment.

A2.2.6.5. Interference rejection testing shall be performed per A1.2.6.5 to determine when the system is no longer capable of providing reliable information to the LPSE. The test outlined in section 2.5.7 of RTCA DO-229D change 1, shall be performed to determine this threshold. Record the level of interference that caused the solution to fail. Verify that the system zeroes the position messages if interference is increased beyond this level.

A2.2.6.6. Accuracy testing shall be performed to determine the NACp per A1.2.6.6. Equipment shall output a NACp appropriate to the accuracy level. Perform the test in RTCA DO-229D change 1, section 2.5.8.

A2.2.6.7. NACv testing must be performed per A1.2.6.7, to determine the NACv capability of the GPS system. AC 20-138C, Appendix 4 describes bench test procedures that can be used as an acceptable means to determine NACv. All equipment should use the tests in AC 20-138C, section A4-3 through A4-8 to demonstrate velocity accuracy as navigation accuracy category - velocity (NACV) = 1. Manufacturers that want their equipment qualified to NACV = 2 must also complete the test in section A4-9. Under the conditions described in AC 20-138C Appendix 4, a unit may fail sooner to interference than an aviation grade unit may fail. This is acceptable as long as the failure due to interference is detected and the unit does not transmit false or misleading information.

Appendix 3. Considerations for Radio Frequency (RF) Exposure Safety

A3.1. RF Exposure Safety Introduction

A3.1.1. This appendix provides information related to ensuring RF exposure safety of LPSE. Because LPSE may be used in close proximity to the pilot or passengers, RF exposure levels must be determined to ensure safe operation of the device. This appendix does not an attempt to provide a means to show compliance with RF exposure standards. The intent of this appendix is to highlight the need for manufacturers and system interrogators to ensure the potential risks due to RF exposure is properly addressed and ultimately ensure LPSE is safe to use.

A3.2. RF Exposure Safety Considerations

A3.2.1. Rules covering safe RF exposure levels is governed by the locality where the LPSE will be used. This appendix references Federal Communications Commission (FCC) guidelines used in the US. References to EUROCONTROL and United Kingdom documents are also provided. While the referenced European documents have no legal standing in the US, they may provide a better understanding of the risk RF exposure may pose. There may be other useful documents, this appendix references three, they are:

(1) Federal Communications Commission Office of Engineering & Technology, OET Bulletin 65 Edition 97-01, *Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields*, dated August 1997

(2) EUROCONTROL, STA/R/460/0001/1, *Study to Address the Detection and Recognition of Light Aircraft in the Current and Future ATM Environment, Issue 1.0, Final Report*, dated 31 March 2005

(3) Health Protection Agency, HPA-RPD-031, *Exposure to EMFs from Lightweight Aviation Transponders*, dated September 2007

A3.3. FCC Guidelines

A3.3.1. Guidelines found in FCC OET Bulletin 65 Edition 97-01, provides a distinction between mobile devices and portable devices.

A3.3.2. Mobile Devices. Depending on how the LPSE unit is installed , it may be considered a mobile device. Mobile devices are intended to operate at least 20 cm (about 7.9 inches) away from the user or nearby persons. Due to their proximate location to humans, these devices can be evaluated based on maximum permissible exposure (MPE). A description of mobile devices can be found in OET Bulletin 65 Edition 97-01, pages 14, 40 and 73.

A3.3.3. Portable Devices. Depending on how the LPSE unit is installed, it may be considered a portable device. FCC guidance indicates portable devices are intended to operate within 20 cm (about 7.9 inches) of the user or nearby persons. These devices are evaluated based on limits for specific absorption rate (SAR). Because these devices are much closer to humans, SAR calculations are much more complicated. SAR calculations are explained in OET Bulletin 65 Edition 97-01, section 2 and appendix A. Portable devices are defined and described in OET Bulletin 65 Edition 97-01, pages 14, 40, 73 and 74.

A3.4. EUROCONTROL LAST Study Final Report

A3.4.1. The LPSE is not a direct derivative of the European work on the Light Aviation SSR Transponder, (LAST), but it benefits from the research and study done for it. As part of the LAST research, the United Kingdom (UK) Civil Aviation Authority (CAA) commissioned the UK National Radiological Protection Board (NRPB), now the Radiation Protection Division of the Health Protection Agency (HPA) to study potential health risks of LAST equipment. This study is documented in the restricted report: "Cooper TG and Mann SM (1998). Exposure to Pulsed UHF Radiation Transmitted by Racal Lightweight Transponder. Contract Report NRPB-M954." A brief summary of this report can be found in EUROCONTROL, STA/R/460/0001/1 section 6.5 page 24. Fortunately, the UK CAA commissioned another more appropriate study from the HPA, which is documented below.

A3.5. UK Health Protection Agency LAST Study

A3.5.1. The UK CAA also commissioned a study from the HPA that looked at RF exposure risks of light weight transponder devices titled HPA-RPD-031, *Exposure to EMFs from Lightweight Aviation Transponders*. The HPA study of the RF exposure from a LAST device is useful as baseline set of data in characterizing the RF exposure risk from the LPSE.

A3.5.2. Maximum power.

A3.5.2.1 The HPA study considered two power levels for the LAST, see HPA-RPD-031, section 2.2.2 and Table 1, page 3, Note: the label LPST is used instead of LAST. Table 21 summarizes transponder, LPSE, and LAST device power specifications:

Device	Minimum Output Power		Maximum Output Power	
	dBW	watts	dBw	watts
DO-181E Class 1	21.0	125	27.0	500
DO-181E Class 2	18.5	70	27.0	500
LPSE	18.5	70	27.0*	500*
LAST 1	18.5	70	19.0	80
LAST 2	14.5	25	15.0	30

Table 21 Power classes of transponder, LPSE and LAST Summary

** Note: the maximum output power for the LPSE has not been separately specified, the maximum power available for the LAST 1 is more suitable, and allows safe operation closer to the operator.*

A3.5.2.2. The analysis of the LPSE must be based on the maximum possible power the design will allow, therefore limiting the maximum possible power while maintaining the required minimum power will allow optimal options for use of the LPSE in proximity to operators and the general public.

A3.5.3. Reply rate limit.

A3.5.3.1. The HPA study considers a reply rate limit that matched that of the standard transponder. The LPSE has been tailored to allow a lower reply rate limit; these are presented in Table 22 for comparison.

Transmission	Transponder 2007		European Traffic 2020		LPSE	
	count	µsec RF	count	µsec RF	count	µsec RF
Mode A/C replies	500	3375	475.3	3208.3	100	675
Short Mode S replies	34	1020	27	810	19	570
Long Mode S replies	16	928	3.6	208.8	10	580
Short squitters	1	30	1	30	1	30
Long squitters	2.2	127.6	2.2	127.6	2.7*	156.6
Total µsec RF		5480.6		4384.7		2011.6
Duty cycle		0.55%		0.44%		0.20%

Table 22 Reply rates of transponder, LAST and LPSE Summary

** Note: during the 18 seconds of higher transmission rate for altitude rate changes this value is 3.7 long squitters per second.*

A3.5.3.2. Analysis of the LPSE may be required by the FCC to be based on the maximum possible reply rate the design will allow, therefore limiting the maximum possible reply rate while maintaining the required minimum reply rate will allow optimal options for use of the LPSE in proximity to operators and the general public.

A3.5.4. Time averaged power.

A3.5.4.1. The HPA study calculates the average power from the duty cycle such as in Table 22 above, and peak power output such as in Table 21 above. Combining this information in Table 23 is the time averaged power for the LAST and LPSE. The values in Table 23 are based on the transponder reply rate for the LAST and reply rate limit specified for the LPSE. The time average power is calculated for two power levels for the LPSE, one at the maximum power permitted by the MOPS and the other at a restricted power to a level more suitable for a portable device like the LPSE. The table shows the normal values, but during the higher transmission rate for altitude rate changes, (see section **A1.2.5.3**), the LPSE maximum and restricted time average power are 1.03 and 0.166 watts respectively.

Device	Peak Power (watts)	Time Average Power (watts)
LAST 1	80	0.44
LAST 2	30	0.164
LPSE maximum	500	1.01
LPSE restricted	80	0.161

Table 23 Time averaged power of LAST and LPSE

A3.5.5. LAST RF exposure results summary.

A3.5.5.1. The HPA study concentrates on determining the SAR associated with the LAST. Calculating the SAR of the LPSE will be consistent with the more rigorous requirements of the FCC associated with a portable device. A portable device is allowed within 20 cm of the body (see references in section **A3.3.3** above), so there is a greater burden to show that the device will be safe for pilots, operators, and the general public.

A3.5.5.2. The analysis of the LAST referenced in HPA report, HPA-RPD-031 has promising results for the implementation of LPSE as a device that may be operated on small aircraft close humans. This may be particularly true if the implementation adheres to the reply rate limits specified in this TSO, and limits the possible maximum power to something like 80 watts. Under these conditions the LPSE has time averaged power similar to the 30 watt maximum LAST transponder. Review of the material in HPA-RPD-031, particularly sections 4 and 5, may provide valuable insight in the evaluation of any LPSE design for RF exposure levels.

A3.5.5.3. Compliance with FCC regulations is necessary for the licensing and approval of RF transmitting devices in the US and will help assure the RF emission exposure safety of the LPSE.

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